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Smart Services for Energy Communities: Insights on Options and Priorities from a Multicriteria Mapping Study in Germany

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SMART SERVICES FOR ENERGY COMMUNITIES: INSIGHTS ON OPTIONS AND PRIORITIES FROM A MULTICRITERIA MAPPING STUDY IN GERMANY

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Abstract Energy Communities are finding their way into the local energy systems as new regulations surge. However, they often lack resources due to their limited size, and depend heavily on subsidies for providing competitive offerings. In parallel, new technologies support the development of smart services for the energy market and provide chances for increasing the competitiveness of energy communities. This paper utilizes the multi-criteria mapping (MCM) method to discuss with stakeholders from energy communities in Germany the relevance and priorities for realizing specific smart services. A general ranking, as well as four perspective-based rankings, are analyzed by discussing contrasts and uncertainties. The results provide relevant insights on potentials from each service and a basis for the design of new information systems and architectures for energy communities.

1   Introduction

New regulations are setting ways for further development of the energy market worldwide (Spence 2019; Vasily Kupriyanovsky et al. 2019). In Germany, the energy industry is strongly regulated and generates a positive economic impact after the German Renewable Energy Sources Act (EEG), increasing investments and employment (Hillebrand et al. 2006), as well as serving as a model for legislation in other countries (Lehr et al. 2008). Consequently, projects on the demand side emerged (Palensky and Dietrich 2011) and new concepts, such as Smart Energy Communities (SECs), found their way into the regulatory systems. SECs consist of a group of households with different forms of electric loads and technologies integrated into a control system, which actively manages generation and demand in the community (Fazeli et al. 2011). Recently, citizens started to engage in local energy systems due to community identity, social norms, trust and environmental concern (Kalkbrenner and Roosen 2016; Fazeli et al. 2011; Massey et al. 2018).

In parallel, technological advancements pave the way for 'smart' energy services (SES) (Mathiesen et al. 2015; van Dinther et al. 2021) using a smart grid architecture based on 'prosumers' - users that consume and produce energy (Grijalva and Tariq 2011). Services are smart when based on hard field intelligence, and are processing a large amount of data and giving decision-makers more visibility into their business (Allmendinger and Lombreglia 2005), using interconnected Information Systems (IS) for data acquisition, algorithms, data reports and interfaces for visualization and configuration (Palensky and Dietrich 2011; Beverungen et al. 2019).

While some studies discuss energy communities with a focus on choosing the type of renewable energies (Karunathilake et al. 2019), their ecosystems (Vernay and Sebi 2020) or social innovation aspects (Caramizaru and Uihlein 2020), current literature on SECs focuses on specific services and processes, such as big data analysis (Zhou et al. 2016), smart meters (Anda and Temmen 2014), peer-to-peers interconnected smart homes (Steinheimer et al. 2012) and smart Internet of Things (IoT) (Giordano et al. 2020). New business models based on SESs, including peer-to-peer (P2P) marketplaces, microgrids or virtual power plants derive from energy generated intelligently and optimized to balance with its demand (Paukstadt and Becker 2019). Such models use smart systems, providing a more holistic approach rather than focusing on specific services or only on smart grids (Lund et al. 2017).

SECs benefit from SES as they secure reliability, enhance market service, minimize environmental impact, reduce costs and improve the use of renewable energy (Wang et al. 2015), following the development goals from United Nations (Leal Filho et al. 2021). These local networks have limited resources to invest in many technologies as they count mainly on investments from citizens in the region (Dóci et al. 2015). No study has provided yet an overview of SES, highlighting their potentials and drawbacks, facilitating their prioritization by SECs.

This paper addresses this gap by discussing smart options according to their potential of contribution to improve services and processes within SECs. The study answers the following research questions:

- What are the options and priorities for smart services applied to SECs in Germany?
- What challenges and opportunities for SECs and IS solutions derive from these options?

Figure 1 depicts the research agenda and expected outcomes. After an expert group defined the options of smart services and four necessary perspectives to assess them, stakeholders were selected according to these perspectives. The options were then assessed (ranking) and discussed (appraisal) during guided interviews. This assessment contributes to the prioritization of smart services and provides an analysis of current uncertainties and potentials in the energy market for smart communities.
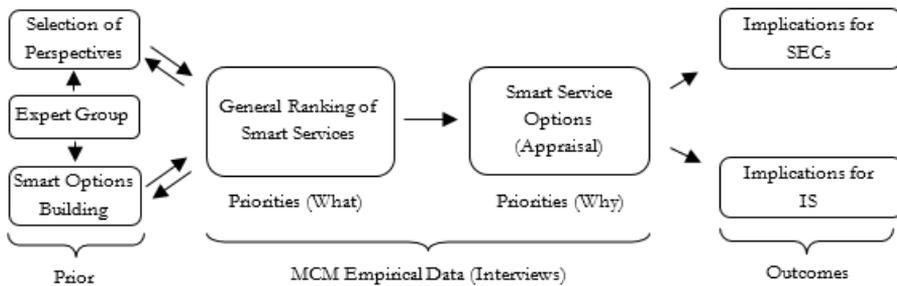

Figure 1: Research Agenda

The remainder of the paper is structured as follows: Chapter 2 explains the methodology and its steps to assess smart options. Chapter 3 discusses the results derived from the analysis, while Chapter 4 provides the main conclusions and contributions for SECs and IS design, as well as insights on further research.
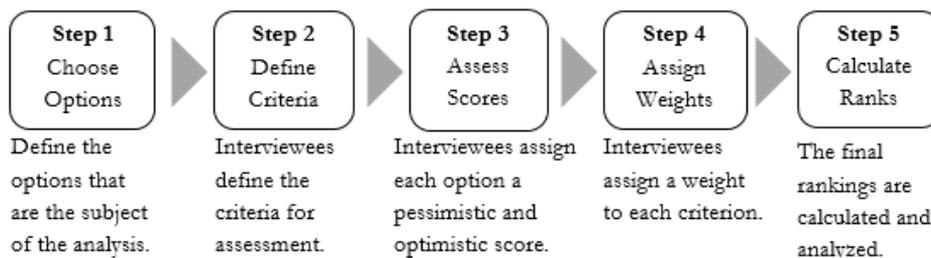
2 Methodology

Researchers, industry and policymakers have assessed risk related to decisions and technologies (Waterstone 1992), fostering studies of their risk perception (Slovic 1987). Adopting technologies require investments and these assessments provide positive and negative aspects of the evaluated objects, reducing risks. Different methods to assess and appraise risk have been developed (Covello and Merkhofer 1993; Horvath and Zuckerman 1993), especially related to technology (Lefley 1997; Stirling 2008). Methods, such as RT Delphi (Gordon and Pease 2006) or cost-effective models (Hubbard 2014), have been applied to the prioritization of technologies. However, these methods fall short when assessing the uncertainties of new technological developments. In this sense, the Multicriteria Mapping Method (MCM) provides an extensive view of potential options.

MCM provides a structured analysis of uncertainties applied to various domains (Stirling and Mayer 2001; Hansen 2010; Shankar et al. 2002). This analysis is based on insights and information from stakeholders of a given industry (Shankar et al. 2002; Donaldson and Preston 1995; Carpenter et al. 2003). Researchers using MCM refer to these stakeholders to provide an analysis with different views and perspectives on the same subject taking into consideration these uncertainties (Hansen 2010; Shankar et al. 2002; McDowall and Eames 2007).

This study used pre-structured options introduced and assessed numerically. Pre-structured surveys are applied to study diversity, defining the objects of analysis beforehand (Jansen 2010). This descriptive analysis aims to prioritize existing options empirically within certain stakeholder groups. A survey is qualitative if it does not count the frequencies of categories, but searches for empirical diversity in the analyzed objects, even if these results are expressed in numbers (Jansen 2010). MCM combines a numeric assessment to rank the options and visualize uncertainty, but focuses on discussions why some options are considered more relevant.

The analysis of this paper follows the steps suggested by Coburn (2016) (see Figure 2). MCM provides an online platform[1] to guide the interview process and support researchers in setting up the interview environment, allowing stakeholders to understand the pre-defined options and move along the research steps. A prior preparation phase took place to define these options and the stakeholder groups by inviting experts in the field to discuss and define the options for SECs.

Step 1 Choose Options	Step 2 Define Criteria	Step 3 Assess Scores	Step 4 Assign Weights	Step 5 Calculate Ranks
Define the options that are the subject of the analysis.	Interviewees define the criteria for assessment.	Interviewees assign each option a pessimistic and optimistic score.	Interviewees assign a weight to each criterion.	The final rankings are calculated and analyzed.

Figure 2: Research Steps from MCM
Source: Stirling and Mayer (2000)

2.1   Selection of Stakeholders (Perspectives) and Smart Options

Ten experts related to the energy market and IS field discussed and developed a list of smart options that affect SEC performance, as a list of smart services for SECs was not found in the existing literature. The expert group included leaders and representatives from energy (three) and IS-related (three) research institutes, energy communities (two), and software companies (two). They defined the smart options based on their expertise, focusing on services that can be improved using current technologies (see Table 1) and the stakeholder groups (see Table 2) to combine different perspectives on the topic. There was no overlap between the experts and the stakeholders. The options below are coded in three-letter acronyms for later visualization and discussions.

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[1] Multicriteria Mapping - https://www.multicriteriamapping.com/

Table 1: Options and Descriptions for Smart Services

| Option	Description (D) and Contribution (C) to SECs
Applications based on Measured Data (AMD)	(D) User behavior information and usage anomaly ground the development of various applications, such as gamification (power savings comparison), individual billing per device, etc.
	(C) Provision of data visualization to show consumers their exact power consumption and provide forecasts.
Peer-to-peer Trade (P2P)	(D) Private individuals, small businesses and producing companies trade electricity. Consumers, producers and storage facilities are networked to communities and trade locally generated electricity with each other.
	(C) Development of trading platforms.
Selection of Energy Mix (SEM)	(D) Different systems are combined and the consumption profile transparently connected with generation capacities. This improves the location planning of companies as they could define it based on preferences in the energy mix from local producers.
	(C) Consumers select their energy mix systematically.
Proof of Origin (POO)	(D) Electricity is transformed from a commodity to an emotional product by proving when and where it comes from.
	(C) Information regarding less-burdened networks is provided and improves the local matching of supply and demand.
Consumption and Production Optimization (CPO)	(D) Consumption and production could be as close as possible to local communities. IS could support the timetable optimization from flexible producers, consumers and energy storages based on very accurate forecasts and equipment management.
	(C) Timetable optimization from flexible producers, consumers and energy storages based on accurate forecasts and equipment management.
Virtual Power Plants (VPP)	(D) SECs aggregate their flexibility to market their surpluses directly.
	(C) Development of a virtual power plant.
New Tariffs (NTA)	(D) New flexible tariffs (dynamic fares) are adapted and provided to users (prosumers and flexible consumers).
	(C) Development of an incentive system to relieve the local power grid and balance the community's residual load, increasing the local matching of production and consumption.
Investment Opportunities (IOP)	(D) People living on low-invested land and in rented houses/flats could participate financially and generate returns through investments.
	(C) Investments from users are part of the electricity costs. Consumers gradually buy shares of a production plant and participate in the revenue, while SECs invest in production and storage as needed.

According to the reality of energy communities in Germany, the expert group selected four perspectives (stakeholder groups) and indicated several stakeholders to take part in an interview session, which lasted between 60 and 90 minutes. In total, 15 stakeholders participated in the study.

Table 2: Group of Stakeholders (Perspectives)

Perspectives / Stakeholders	Participants
Energy Cooperatives	5
Municipal Utilities as Energy Suppliers	5
Energy Providers with New Disruptive Business Models	3
Technology/Software	2
Total	15

2.2 Assigning Scores and Weights based on Criteria

During the interviews, participants were encouraged to create up to three criteria and assess each option according to them. This allows a degree of freedom for stakeholders to indicate the aspects that are important to them when assessing the given options, as the group consists of different expertise. The criteria were grouped into five topics: (1) perspective from consumers (costs and acceptance), (2) external factors (feasibility, regulatory requirements), (3) level of innovation, (4) economical and (5) ecological aspects. Subsequently, participants assigned a pessimistic and an optimistic score to each option on a scale from zero to 100, and weighted each criterion to improve the analysis of uncertainty.
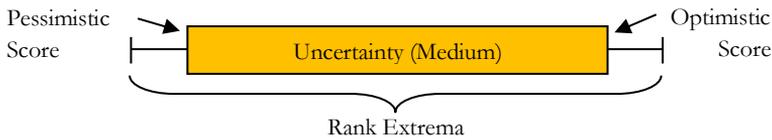
Figure 3: Chart Analysis

This assessment produced a chart and Figure 3 depicts how it displays the results. Options can rank high or low and the difference between the optimistic and pessimistic scores reflects the level of uncertainty. For that, the medium of the scores was considered. The highest and lowest scores are reflected in the extrema line.

3   Results

The general chart provides an overview of how all options are ranking considering their medium values. Stakeholders ranked higher the option Applications based on measured data (AMD), while they were more pessimistic regarding the selection of energy mix (SEM). P2P Trade has a higher level of uncertainty, indicating disagreements among them regarding the developments of such a trading scheme.
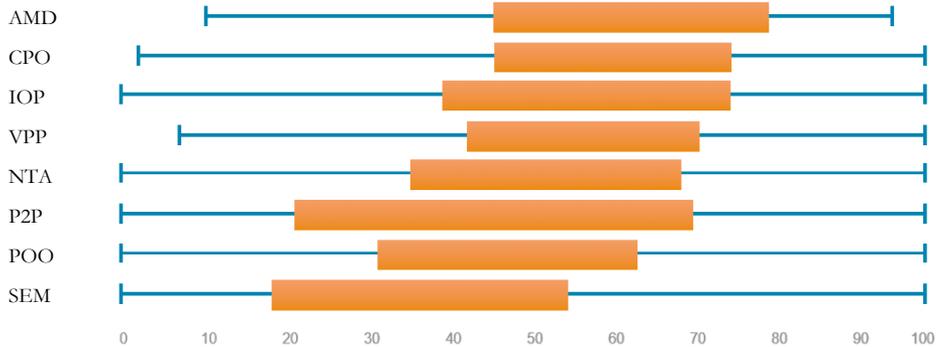

Figure 4: General Ranking of Options (n=15)

Despite the indications of this first chart, a view according to the perspectives highlights the differences in stakeholder groups (see Figure 5). For example, technology-related stakeholders are less optimistic about the optimization of consumption and production (CPO) than the other groups. Additionally, Municipal Utilities are more positive about the option of Virtual Power Plants (VPP).
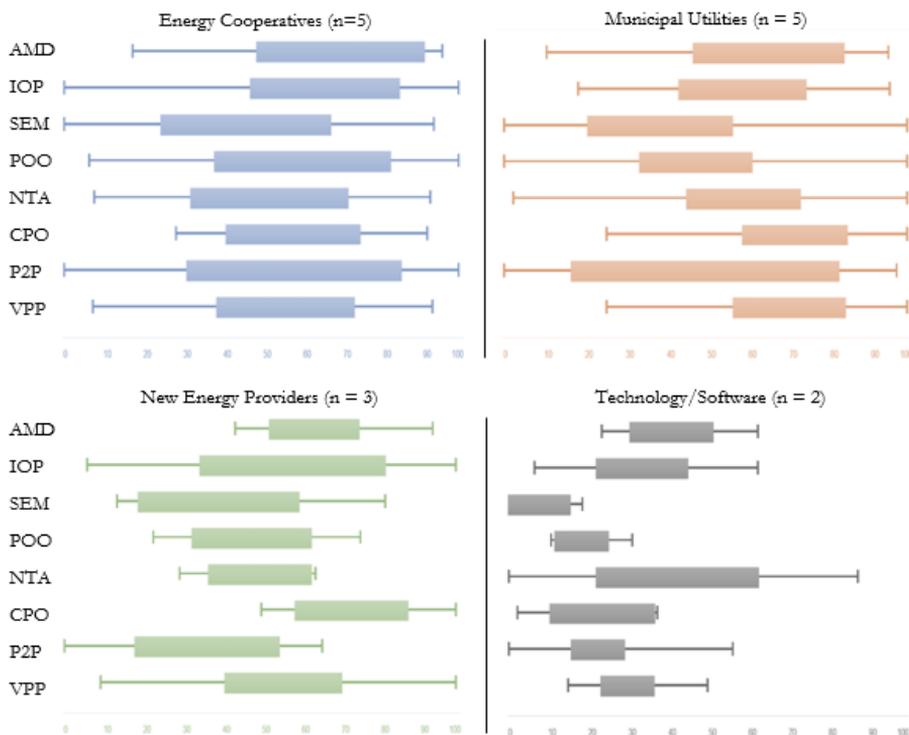
Figure 5: Ranking of Perspectives: Stakeholder Groups.

The observed high level of uncertainty derives from the optimistic and pessimistic scores, assigned and justified by the stakeholders. Besides the numerical assessment, the reasons for the given scores were discussed, as shown in the table below.

Table 3: Optimistic and Pessimistic Views on the Options

Opt.	Optimistic View	Pessimistic View
AMD	- Smart meters produce data for the predictive models of consumption to provide an appropriate supply. - The option provides consumption indication for users.	- Data transfer between gateway and terminals is not yet standardized. - Different interfaces make access non-discriminatory and only companies with the same technology can act as the provider. - Data protection concerns limit the analysis of measured data
IOP	- Participation from citizens increase acceptance and accelerate the energy transition.	- New regulation concerning direct transactions in the market brings concerns that no return on equity investments would payout.

		- SECs must receive support from local stakeholders.
SEM	- Relevant option for the future, but the technical feasibility is very difficult in contrast with the benefits.	- Most customers find it sufficient to obtain green electricity via certificates. - Consumers have emotional attachments to producers and types of energy production.
POO	- Strongly related to P2P trading as the origin is clear in such transactions.	- Green electricity certificates are rather opaque and guarantees of origin need to become more accurate. - Most customers are sensitive to price and do not understand the issue.
NTA	- Uncertainty whether incentive systems with variable prices lead to a behavioral adjustment.	- Relocation of power consumption is difficult for many consumers in private and commercial areas. - Electricity would continue to be consumed when needed, without short-term price elasticity. - A necessary reform of network charges might not take place soon.
CPO	- Seen as the main reason for starting a community. - Balancing generation and consumption done at a regional level.	- It is necessary to define what to connect and record. - Privacy issues can hinder the implementation. - Dependent on the application based on measured data (AMD) and smart meters.
P2P	- Considered the future of the energy market. However, it requires a regionalization of trade and marketplaces.	- Current market is too complex and not transparent. - A community could be reached through a pooling of actors and, therefore, be organized in a common control group without real P2P trading. - A community in a control group is already working today, so true innovation could surge from the emersion of a genuine regional marketplace.
VPP	- For a community, the offering of flexibility is interesting. - The option is reasonable from the physical point of view and logical for the network.	- There is a lack of a clear framework to market it locally. - The individual producer or consumption lacks expertise.

The indication of pessimistic and optimistic aspects also included challenges and potential applications for the options. New challenges concern AMD, such as local injection peaks or high withdrawal peaks due to e-mobility. Nevertheless, smart meters help to predict such consumption. According to stakeholders, the benefit of cooperative electricity could surge through "add-ons" after refinement of the electricity product. Modular product architecture supports the development of interchangeable options (Dahmus et al. 2001). However, technology-related stakeholders are less optimistic because of the lack of standardization. In addition, data protection could hinder such analysis, which goes in line with recent data-protection concerns regarding the deployment of smart meters (Erkin et al. 2013).

Regarding IOP, the participation from citizens is relevant, but requires support from local stakeholders, municipal utilities, investment banks, government, etc. New

energy providers are concerned with return on investments due to new regulations of the direct market. This affects the uncertainty of this option, despite the relevance of citizen participation to finance renewable energy in Germany (Yildiz 2014).

SEM ranks low as stakeholders believe customers are satisfied with current certificates for green electricity. Its technical feasibility is difficult, and consumers are, sometimes, emotionally attached to certain types of electricity. Despite the willingness of energy cooperatives to source their electricity from renewable energies, if that incurs higher electricity costs, these would have to be justified. In this line, POO performed differently in the stakeholder groups as they differ in the level of concern from consumers regarding energy origin. However, energy consumers, when asked to make an active choice between a green and a standard energy provider, choose mostly a green program (Hedlin and Sunstein 2016).

Concerning NTA, participants differed on its impact on behavioral adjustment. Many interviewees claimed electricity would continue to be consumed when needed, diminishing the chances for short-term price elasticity. Nevertheless, they claim CPO is necessary to start an SEC. Efforts should focus on balancing generation and consumption as much as possible at a regional level and should also be network-optimized. New energy providers claim installations should be built where the consumption is located, defining what to connect and record.

Energy cooperatives indicated the motivation from their members not only economically, but also intrinsically or ideationally towards P2P. However, stakeholders from the municipal utility group are uncertain about the need for such trading as a community in an existing control group might be sufficient and this implementation can be costly. ICT and control systems are necessary to enable P2P energy trading in local energy markets (Zhang et al. 2017).

Participants agree that a market possibility is necessary for communities to act as a VPP. As renewables become more prevalent, the need for local governance increase. Representatives from municipal utilities were more optimistic about this option and claimed that, even though the market is not ready yet, the shift to the end consumer's perspective is shaping the energy transition. From the technological aspect, some

studies developed algorithms able to aggregate the capacity of different energy resources (Pudjianto et al. 2007; Ruiz et al. 2009; Pandžić et al. 2013).

The views on the options support SECs to decide on the adoption of smart services, defining priorities and investments based on specific needs and market reality. The next chapter presents the implications for research and practice.

4. Conclusions and Implications for Research and Practice

Stakeholders examined technology-based options that influence processes within SECs in Germany through the MCM method. Eight options were developed by an expert group and stakeholders assessed them, indicating priorities. Participants indicated AMD as a high priority for SECs once it also grounds the development of further smart options based on the application of smart meters. The indication and prioritization of smart services answer the first research question, contributing to future solutions for digital ecosystems platforms in the energy industry. Furthermore, stakeholders discussed optimistic and pessimistic aspects for each option, answering the second research question regarding challenges and opportunities. In addition, they indicated that regulatory challenges, data privacy, and the cost-benefit of available technologies are able to hinder the application or reduce the relevance of some options for German SECs.

The predominance of positive aspects around applications based on smart meter data indicates a potential for research on data generated in SECs as a way to determine optimization practices and balance between energy production and consumption.

Stakeholders pointed out that energy communities need to integrate processes and dispersed data to a high degree, as well as to integrate and coordinate different actors in a cross-organizational environment. Although smart meters are not yet widely used, most options benefit directly from their availability. Taking into account the current resource limitation of the energy communities in Germany, either service platforms for several communities or decentralized architectures seem necessary for realizing SECs. Stakeholders shared their opinion on technological developments, the behavior of electricity consumers and current regulations, supporting SECs in

their strategic planning and providing directions on technological demands for smart services in this industry.

SECs benefit from the development and improvement of smart services based on recent IS technologies and the indication and assessment of SES are able to guide IS designers to prioritize their offerings in the field. However, systems should be designed to allow the future aggregation of new functionalities into a complete service system (Lund et al. 2017). That requires an integration of information systems across different organizations. Furthermore, new systems could assume functionalities that are typically performed by intermediaries, co-evolving towards decentralized solutions matching buyers and sellers (Alt 2018) or, in the case of SECs, matching the prosumers. Adopting innovative technologies, such as Blockchain, can support cooperative principles in marketplaces (Kollmann et al. 2020) and foster this change towards decentralized systems.

IS solutions should address the challenges and potentials of technology implementation to support SECs in the optimization of the community. SECs can benefit from the development and improvement of smart services based on recent IS technologies. Among the various contributions, systems can (1) support to predict demands, manage supply and ground investments; (2) draw relevant analysis based on the data; (3) support the emission of certificates regarding the energy, allowing a selection of energy mix; (4) support relieving the power grid and balancing residual load; (5) support the matching of supply and demand, optimizing production; (6) provide and manage incentives through new tariffs, according to usage; (7) support the virtual trade of generated energy; (8) support smart contracts and peer-to-peer trading.

Furthermore, public policies could support the implementation of such technologies applied to the energy market, influencing how SECs will adapt to the recent regulatory changes.

Although the results of the MCM provide indications, conclusions about stakeholders' preferences should be made with caution due to the small number of interviewees. This also affected the balance between the groups, as the total of

stakeholders per perspective is not equal. The inclusion of large energy companies could improve the assessment due to the risk SECs might represent to their business.

Researchers can use these results and methodology to investigate further the options of smart services and to identify possible demands for new integrated information systems in the energy market. Moreover, further research could use MCM to provide a deeper analysis of the source of uncertainty for each stakeholder group and weighting justifications. As some of the options for smart services are already available, market-related information for these options could be explored in addition to the analysis of this paper. Although the paper focuses on the current scenario of German SECs, communities in other regions can benefit from the analysis.

Acknowledgement

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